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1/77

Request for grant of a patent

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- 5 SEP 2002

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1. Your reference

P31824/JED/JDB

2. Patent Application Number
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0220626.6

3. Full name, address and postcode of the or of
each applicant (*underline all surnames*)

Robert Gordon University
Schoolhill
Aberdeen
AB10 1FR

Patents ADP number (*if you know it*)

If the applicant is a corporate body, give the
country/state of its incorporation

United Kingdom

822 0816002

4. Title of the invention

"Apparatus for Controlling the Launch, Secure Positioning and/or
Recovery of Marine Based Equipment Situated in Sea or River
Currents"

5. Name of your agent (*if you have one*)

Murgitroyd & Company

"Address for service" in the United Kingdom
to which all correspondence should be sent
(including the postcode)

165 - 169 Scotland Street
Glasgow
G5 8PL

Patents ADP number (*if you know it*)

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Country

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Claim(s) -

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11. I/We request the grant of a patent on the basis of this application

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Date 04/09/2002

12. Name and daytime telephone number of
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1 "Apparatus for Controlling the Launch, Secure
2 positioning and/or Recovery of Marine Based
3 Equipment Situated in Sea or River Currents"
4

5 Technical field
6

7 The invention relates to a marine environment
8 location device such as may be used for controlling
9 the launch, positioning and recovery of a tidal
10 turbine or other equipment. It should be noted that
11 the example of a tidal turbine is used herein but
12 the invention is not limited to such uses.
13

14 Background art
15

16 Tidal currents offer a considerable source of
17 sustainable energy at various sites throughout the
18 world, usually within easy reach of land and in
19 relatively shallow waters. Tidal currents are
20 created by movement of the tides around the earth
21 producing a varying sea level, dependant on the
22 phases of the moon and sun. As the sea levels vary,

1 so the waters attempt to maintain equilibrium
2 subject to gravitational forces, thus inducing flow
3 from one area of sea to another. This flow is
4 modified by a number of factors such as, the
5 Coriolis forces due to the earth rotation,
6 earth/moon/sun alignment, local topography,
7 atmospheric pressure and temperature and salinity
8 gradients. The major advantage of tidal power
9 generation is its regularity, which can be predicted
10 for years in advance.

11

12 According to a study by the ETSU (Energy Technology
13 Support Unit) the United Kingdom may obtain up to 20
14 percent of its total electricity by using these
15 systems to collect energy from fast moving tidal
16 currents that exist in channels and offshore areas.
17 Similar resources have been noted to exist elsewhere
18 such as in the Straits of Messina, between Sicily
19 and mainland Italy.

20

21 The most powerful flows tend to occur in areas of
22 restriction, either by width or depth, but for the
23 same reasons are not suitable for widespread
24 exploitation by large, fixed devices which require a
25 minimum rotor area, and therefore water depth, to
26 justify the costs of installation and maintenance.
27 It is assumed from the outset that new tidal barrage
28 systems are unlikely ever to be pursued due to their
29 inherent properties of high cost, delayed financial
30 return, and serious environmental consequences.

31

1 The considerable size of the available resource has
2 attracted various proposals for its exploitation.
3 The following represents the existing systems within
4 the field of tidal current energy extraction. It is
5 assumed that power transmission problems will be
6 equal for any system, and that all systems will
7 require some form of non-toxic anti-fouling agent.

8
9 There also exist operational environmental impacts
10 common to all methods of tidal power generation,
11 such as, an inherent risk of collision damage to
12 fish and marine mammals, redirection of currents and
13 the sediments and food particles contained within
14 them, and shipping, particularly fishing.

15
16 A first type of tidal current energy extraction
17 system encountered on the market is the Monopile
18 system. This technology is well known and
19 understood by contractors familiar with the offshore
20 oil industry. It consists of twin axial flow
21 turbines, each turbine driving a generator via a
22 gearbox, mounted on streamlined cantilevers either
23 side of a circular section, vertical steel monopile.
24 It is anticipated that a number of structures will
25 be grouped together in 'farms'. The planning of
26 such a tidal 'farm' would need to be accurately
27 modelled for wake effects, as once installed, the
28 monopile is expensive to re-site. In addition,
29 operational depth is restricted to the 20m - 35m
30 range. Concerning the installation and maintenance,
31 monopile systems require a hole to be drilled in
32 suitable bedrock and the base of the turbine tower

1 is secured within the socket so produced. Existing
2 monopile support mechanisms for presenting a tidal
3 turbine to the tidal currents are expensive, thus
4 making only a few sites economically viable for
5 power generation and requiring considerable sub sea
6 engineering expertise.

7
8 The current monopile systems permit raising the
9 turbines above water level for maintenance and
10 repair, which is beneficial, but the long-term (i.e.
11 20 years) reliability and corrosion resistance of
12 the necessary mechanism must be questionable. The
13 protrusion of the piles above sea level would reduce
14 the likelihood of impact with passing vessels.

15
16 Concerning the environmental and decommissioning
17 issues, the impact of installation would be
18 considerable, especially to the benthic flora and
19 fauna, but subsequently the piles may become areas
20 of shelter and therefore, populated. To minimise
21 the danger to shipping and fishing, decommissioning
22 would require complete removal of the piles, which
23 would disturb the benthic population once again.

24
25 A second type of tidal current energy extraction
26 system that exists in the prior art is the floating
27 tether. This floating tether device is anchored to
28 the seabed with a mooring cable and suspended clear
29 of the seabed using a flotation buoy. The axial
30 flow tidal current turbine is free to position
31 itself into the direction of the tidal flow, which
32 obviates the need for a yaw mechanism.

1
2 Several prototypes have already been developed
3 including a 10-kilowatt device tested in Scotland in
4 1994. At present, the arrangement is unlikely to be
5 suitable for large power output installations due to
6 the relative sizes of anchor, turbine and float. On
7 occasions of relatively high velocity tidal streams
8 (e.g. spring tides), if the anchor holds, the
9 turbine will be dragged lower in the water with the
10 unwanted potential to collide with the seabed.

11
12 Concerning the installation of the floating tether
13 system, it is relatively quick and inexpensive.
14 However, visual inspection would need to be frequent
15 as the structure is likely to be subject to storm
16 damage and fatigue loading of the cable, leading to
17 possible loss of the supporting float and subsequent
18 sinking of the device, or loss of anchorage and
19 subsequent drifting. Once sunk, the device would be
20 open to damage by the oscillating tidal currents and
21 could prove difficult to recover, whilst a drifting
22 device would potentially cause damage to any other
23 moored turbines in its path.

24
25 Due to the length of tether required and the random
26 positioning of the device at any one time, this
27 arrangement is not suitable for closely grouped
28 tidal farms and a safe spread would fail to make
29 economical use of the power available in a given
30 area. For the same reasons, this type of
31 arrangement would present a hazard to all forms of
32 shipping, large and small. It would, however

1 present a possible solution to a one-off, small
2 scale installation in areas such as the mouth of a
3 sea loch. Concerning the environmental impacts of
4 installation and decommissioning of the floating
5 tether systems, it will be minimal, leaving no
6 footprint on removal.

7
8 A third type of tidal current energy extraction
9 system that also exists in the prior art is the
10 oscillating hydroplane system. In that system, a
11 central post mounted on five legs supports a complex
12 mechanism comprising two interconnected symmetrical
13 hydrofoils. These hydrofoils are used to pump high-
14 pressure oil, which drives an electrical generator
15 via a hydraulic motor. At the end of each stroke,
16 the hydrofoils are tilted to give the required angle
17 of attack to produce the return stroke, thus
18 creating an oscillating motion.

19
20 Concerning the installation and maintenance, at
21 present, the oscillating hydroplane system does not
22 yet possess a launch and recovery mechanism. As a
23 result of the constant oscillations and considerable
24 number of moving parts, it is probable that this
25 device will be subject to high dynamic loading and
26 subsequent fatigue stress. The upward stroke of the
27 hydrofoils will tend to lift the device off the
28 seabed and hence increase the possibility of it
29 being washed away at high tidal stream velocities.

30
31 Concerning the environmental impacts of installation
32 and decommissioning of the oscillating hydroplane

1 systems, they are expected to be minimal, leaving no
2 footprint on removal. However, this cannot be
3 confirmed until a launch/recovery mechanism is
4 proposed. Using high pressure oil as a means of
5 power transmission does however introduce the
6 possibility of pollution in the event of leakage.

7
8 With these existing systems and designs, it is a
9 problem that their instabilities during operations
10 as well as during launch and recovery, if possible,
11 might cause damage. In addition, since these
12 systems are becoming larger and larger, the frequent
13 installation and maintenance operations will become
14 more and more difficult and expensive.

15
16 Summary of the invention

17
18 It is an object of the present invention to obviate
19 or mitigate the problems of locating marine
20 equipment in a flowstream by devising an apparatus
21 capable of controlling the launch of said equipment,
22 securing said equipment in position and permitting
23 recovery for maintenance, repair or re-siting. The
24 present invention also permits the launch and
25 recovery to be carried out using a non-specialist
26 but suitably equipped vessel.

27
28 In a first aspect, the invention described herein
29 relates to an apparatus for controlling the launch
30 and recovery of marine equipment attached to it,
31 placed in sea or river currents for location and
32 installation of said marine equipment, wherein said

1 apparatus comprises means for rotating through 180°
2 for generating positive or negative lifts.

3
4 Said rotating means preferably comprises self-
5 rectifying static hydrofoils, which may be capable
6 of passive rotation about an axis such that it
7 maintains alignment with a periodically
8 reciprocating rectilinear flow. Typically,
9 differences in pressure acting on its opposing
10 surfaces due to a predetermined angle of attack
11 causes said rotating means to generate negative or
12 positive lifts.

13
14 Preferably, the rotating means is actuated by an
15 actuating means such that it can be used to generate
16 a variable positive or negative lift.

17
18 Preferably, said actuating means is a hydraulic,
19 pneumatic or electric actuated motor.

20
21 Preferably, symmetrical hydrofoils can be used as
22 rotating means.

23
24 Preferably, said apparatus for controlling the
25 launch and recovery of marine equipment attached to
26 it, is a support framework composed of sub
27 frameworks on which are coupled said symmetrical
28 hydrofoils.

29
30 Preferably, said apparatus for controlling the
31 launch and recovery of marine equipment attached to
32 it, is a multi-legged, self-levelling space frame

1 equipped with a number of hydrofoils, typically at
2 different heights.

3

4 Preferably, the marine equipment attached to said
5 space frame is positioned at or in as close
6 proximity as possible to the centre of gravity of
7 the apparatus.

8

9 Preferably, the space frame is mounted on a number
10 of feet equipped with slippage prevention means,
11 which may be an arrangement of spikes or the like,
12 to typically resist slipping by shear force rather
13 than relying on friction alone such that the
14 negative lift will preferably tend to force said
15 slippage prevention means into the seabed thus
16 resisting the drag forces acting on the space frame
17 tangentially to the seabed.

18

19 **Brief description of the drawings**

20

21 Embodiments of the present invention will now be
22 described, by way of example only, with reference to
23 the accompanying drawings, in which:-

24

25 Figure 1 shows a side view of a space frame in
26 accordance with the present invention, showing
27 a tubular frame allowing the positioning of the
28 hydrofoils at differing heights;

29 Figure 2 in it's upper half shows the passive
30 reversing of the hydrofoils in response to a
31 change in flow direction whilst in it's lower
32 half shows the different movements of

1 hydrofoils of figure 1 actuated by hydraulic
2 motors to create positive and negative lifts
3 during launch, recovery and transitional
4 operations according to the present invention;
5 Figure 2a shows the passive reversing of the
6 hydrofoils in response to a change in flow
7 direction;

8 Figure 3 is a first side view showing the
9 fundamental geometry of the passive reversing
10 mechanism;

11 Figure 3a is a second side view showing the
12 fundamental geometry of the passive reversing
13 mechanism;

14 Figure 3b is a third side view showing the
15 fundamental geometry of the passive reversing
16 mechanism;

17 and

18 Figure 4 shows in details the assemblage of
19 hydrofoils onto the space frame of Figure 1.

20

21 **Detailed description of the invention**

22

23 According to the present invention, the apparatus
24 for launching a marine device from a vessel,
25 securing the marine device whilst in operation on
26 the seabed and permitting recovery to a vessel, for
27 maintenance and repair should be as simple as
28 possible without involving any sophisticated and
29 specialised equipment. This is achieved by means of
30 passive, self-rectifying static hydrofoils, the
31 central shaft (see Figure 3) of which can be rotated

1 through 180° to generate positive or negative lift
2 as required.

3
4 As is shown in Figure 1, the apparatus 1 for
5 controlling the launch, secure positioning and
6 recovery of a marine device comprises a space frame
7 10 for attaching to any desired marine device such
8 as power extraction equipment which may comprise a
9 tidal turbine (not shown), a hydrofoil support frame
10 to accommodate the self rectifying hydrofoil
11 mechanisms 12 and hydraulically operated legs 11 for
12 levelling of the apparatus 1. The feet 14 are
13 equipped with spikes or similar serrated attachments
14 (not shown) to initiate grip on the sea or river
15 bed.

16
17 The hydrofoils 12 are inclined in such a way as to
18 generate a significant downforce as a result of the
19 stream flow over their surfaces. This downforce
20 will push the apparatus 1 into the seabed, and,
21 since the actual applied force will be proportional
22 to the square of the velocity of the fluid passing
23 over them, the apparatus 1 will be more securely
24 fixed as the streamflow velocity increases. By this
25 means the apparatus can overcome overturning moments
26 applied to the marine device that it supports.

27
28 The space frame 10 is shown as arched tubing but is
29 not restricted to shape since any frame
30 configuration offering different levels of mounting
31 point for the hydrofoils 12 will suffice. The
32 apparatus 1 as shown has multiple hydrofoils 12 but

1 any number of hydrofoils 12 will suffice. As is
2 shown in Figure 2, each hydrofoil 12 is mounted on a
3 central shaft 48 such that it may rotate upwards
4 from horizontal (or any angle of inclination above
5 horizontal) through vertical to any angle above
6 horizontal but now pointing in the opposite
7 direction. The angle of attack of the hydrofoils 12
8 is governed by the relative size and positioning of
9 lugs 46 attached to the central shaft 48 and the
10 corresponding lobes 44 attached to an outer shaft
11 (not shown) which is itself fixed to the hydrofoil
12 12.

13

14 In a preferred embodiment, the apparatus 1 according
15 to the present invention comprises a multi-legged,
16 self-levelling space frame 10 equipped with a number
17 of hydrofoils 12 at different heights with any
18 marine device, such as a tidal turbine, it supports,
19 situated as close as practicable to the centre of
20 gravity of the apparatus 1.

21

22 It is anticipated that the space frame 10 will be
23 mounted on a number of feet 14 equipped with spikes
24 (not shown) to resist slipping of the apparatus 1
25 with respect to the river bed (not shown) by shear
26 force rather than relying on friction alone. The
27 number of feet 14A, 14B required will depend on the
28 weight of the apparatus 1; however, the location and
29 the shape of these supporting feet 14A, 14B aim at
30 holding the apparatus 1 in the orientation shown in
31 Figure 1 upwards against the current and thus
32 ensuring the stability of the space frame 10. The

1 negative lift (arrow A) will tend to force these
2 spikes into the sea or river bed (not shown in
3 Figure 1) thus resisting the drag forces acting on
4 the space frame 10 tangentially to the sea or river
5 bed.

6
7 The drag forces acting on the marine device (such as
8 the tidal turbine) attached to the apparatus 1 will
9 naturally tend to apply an overturning moment to the
10 space frame 10 about its rearmost feet 14B, with
11 respect to the direction of flow (arrow F). These
12 forces will however be overcome by positioning the
13 hydrofoils 12 at stations such that the negative
14 lift (arrow A), created by the foremost or upstream
15 (those at the left hand side of the space frame 10
16 as shown in Figure 1) hydrofoils 12 acting over the
17 length of the space frame 10, is arranged to exceed
18 the overturning moment.

19
20 Thus, the space frame 10 is symmetrical about its
21 midpoint M with the hydrofoils 12 being coupled to
22 the space frame 10 in a manner, to be subsequently
23 detailed in a discussion of Figure 2, which allows
24 them to passively reverse with stream flow F to
25 maintain compressive forces in a downwards direction
26 A and restraining moments regardless of tidal stream
27 direction.

28
29 During operation of the apparatus 1, the hydrofoils
30 12 are free to rotate (shown as clockwise in the
31 upper half of Figure 2 and 2a) in response to the
32 change in tidal stream flow F direction in a manner

1 which is shown from left to right in the upper half
2 of Figure 2 to create a negative lift (arrow A) so
3 as to push the apparatus 1 into the seabed.

4
5 When the apparatus 1 is to be installed on the
6 seabed or is to be recovered from the seabed for
7 e.g. maintenance of the apparatus 1, as shown in the
8 upper part of Figure 2, hydraulic motors 30, via a
9 suitable gearing mechanism such as a worm and wheel
10 arrangement 32 (as shown in Figure 3) or chain type
11 mechanism (not shown), are utilised to rotate (shown
12 as anticlockwise in the lower half of Figure 2) the
13 longitudinal axes (i.e. the horizontal axes
14 perpendicular to the stream flow 12) of the
15 hydrofoils 12 through the required angle until the
16 hydrofoils 12 have reached the configuration shown
17 at the right hand side of the lower half of Figure
18 2; for the configuration shown in the lower half of
19 Figure 2, this angle is approximately 180° . It
20 should be kept in mind that the hydraulic motors 30
21 can be replaced by pneumatic or electric motors. In
22 other words, if the apparatus 1 is towed, e.g. by a
23 boat or other vessel or installation at the surface,
24 the hydrofoils 12 will produce positive lift (arrow
25 B) as shown in the lower half of Figure 2. For
26 launch and recovery, this positive lift can be
27 utilised to raise or lower the space frame 10 within
28 the tidal stream. If required, this action could be
29 augmented by forming air tanks within the space
30 frame 10 that can be 'blown' with compressed air to
31 improve the buoyancy of the apparatus 1. If the
32 hydraulic motors 30 use the worm and wheel mechanism

1 32 form of drive, the hydrofoil 12 positions can be
2 altered over a range of positions, thus permitting
3 the apparatus 1 to be 'flown' in the water.
4 Hydraulic connections (and pneumatic connections if
5 required) can be affixed to a supporting marker buoy
6 (not shown) for ease of access.

7
8 Figure 3 shows the mechanism and assemblage of
9 hydrofoils 12, hydraulic motors 30 and worm and
10 wheel drive shaft mechanisms 32 in more detail. The
11 hydrofoils 12 are free to rotate about a central
12 shaft 48, through an included angle of say 160°
13 which will maintain an angle of 10° to the
14 horizontal. The 10° angle effectively becomes an
15 angle of attack when the tidal stream flow F
16 reverses. Thus as the tidal stream 10 reciprocates,
17 the hydrofoils 12 will maintain an angle of 10° ,
18 creating a negative lift (arrow A), which will
19 therefore push the spikes 16 into the seabed and
20 immobilise the space frame 10. As will be described
21 subsequently, positioning lugs 46 mounted on a
22 central shaft 48 provided a stop for locating lobes
23 44 of the hydrofoil 12, such that the hydrofoil 12
24 cannot rotate further than the 160° shown in the
25 upper half of Figure 2.

26
27 By rotating the central shaft 48 through slightly
28 greater than 180° (say 200°), the negative lift
29 becomes positive lift (arrow B) and the space frame
30 10 will rise through the water so that the tidal
31 turbine 90 can be recovered on the vessel (not
32 shown).

1
2 Figure 4 shows in more detail the mechanical
3 assemblage of hydrofoils 12 with space frame 10.
4 The hydraulic motor 30 for actuating the positioning
5 gear is equipped with a drive shaft 32 that is
6 utilised for rotating an indented positioning gear
7 42 or a toothed gear wheel. The positioning gear 42
8 is solidly attached to a central shaft 48 which
9 passes through a bore provided in the larger end of
10 each hydrofoil 12, a section of which is show on
11 Figure 4. The bore of the hydrofoil 12 is provided
12 with a pair of diametrically opposed and inwardly
13 projecting hydrofoil locating lobes 44. The central
14 shaft 48 has a pair of diametrically opposed and
15 outwardly projecting positioning lugs 46, each one
16 of which selectively co-operates with one of the
17 respective pair of diametrically opposed hydrofoil
18 locating lobes 44.

19
20 Thus, by rotating the drive shaft 32, the hydraulic
21 motor 30 actuates or rotates the position gear 42
22 which in turn rotates the central shaft 48. The
23 positioning lugs 46 will contact the locating lobes
24 44 and carry them 44 (and the hydrofoil 12) about
25 the rotational axis of the central shaft 48 until
26 the hydrofoil 12 is in the desired configuration,
27 this being through an angle of approximately 160°
28 until the hydrofoil 12 is in the configuration shown
29 at the right hand side of the lower half of Figure
30 2. At this point, the motor 30 is de-actuated and
31 the positioning lugs 46 will hold the hydrofoil 12
32 locked in this configuration. The rotation of 160°

1 enables the hydrofoil 12 to maintain an angle of 10°
2 to the horizontal in order to provide an angle of
3 attack when the tidal stream F reverses.

4
5 Conversely, the rotation of the central shaft 48 by
6 180° drives the hydrofoils 12 to create a positive
7 lift and in which case, the space frame 10 will rise
8 through water. Figure 3a shows how the attitude of
9 the hydrofoil 12 is changed by a simple 180°
10 clockwise rotation of the central shaft 48.

11
12 The apparatus according to the present invention,
13 can be launched and recovered by a non-specialist
14 vessel, using non-specialist equipment. Indeed if
15 the vessel is large enough, a number of apparatus 1
16 may be launched or recovered in a day without the
17 need to return to port. This will also permit easy
18 access for maintenance and repair. Since apparatus
19 1 possesses few moving parts and no complex
20 mechanisms, it should be inherently reliable.

21
22 Concerning the primary environmental impact of
23 embodiments of apparatus 1 according to the present
24 invention, it would have some impact upon the
25 benthic flora and fauna, and, although the
26 positioning and retrieval of apparatus 1 would be
27 relatively frequent (at least once every year is
28 anticipated), nothing more than temporary localised
29 disturbance is anticipated. There exists some
30 potential for hydraulic oil leakage, but the system
31 contents are minimal so, even in the event of
32 complete system evacuation, any oil contamination

1 would be minor. Operational environmental hazards
2 are in common with the other forms of tidal energy
3 extraction and decommissioning would leave no
4 footprint.

5
6 Improvements and modifications in terms of
7 dimensions and locations of the different parts
8 described above may be incorporated to the
9 hereinbefore described apparatus for controlling the
10 launch and recovery of a tidal turbine without
11 departing from the scope of the present invention.

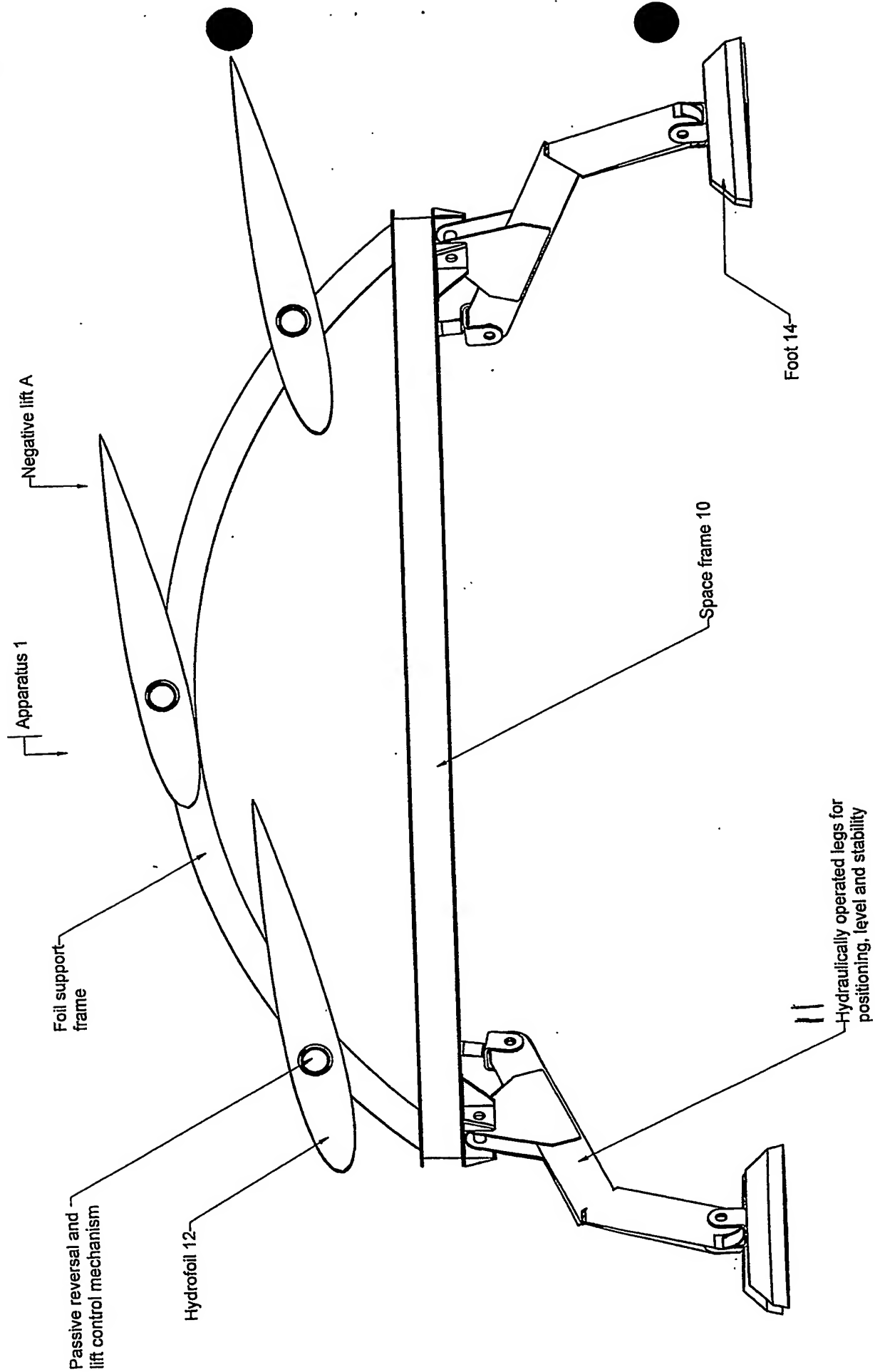


Figure 1

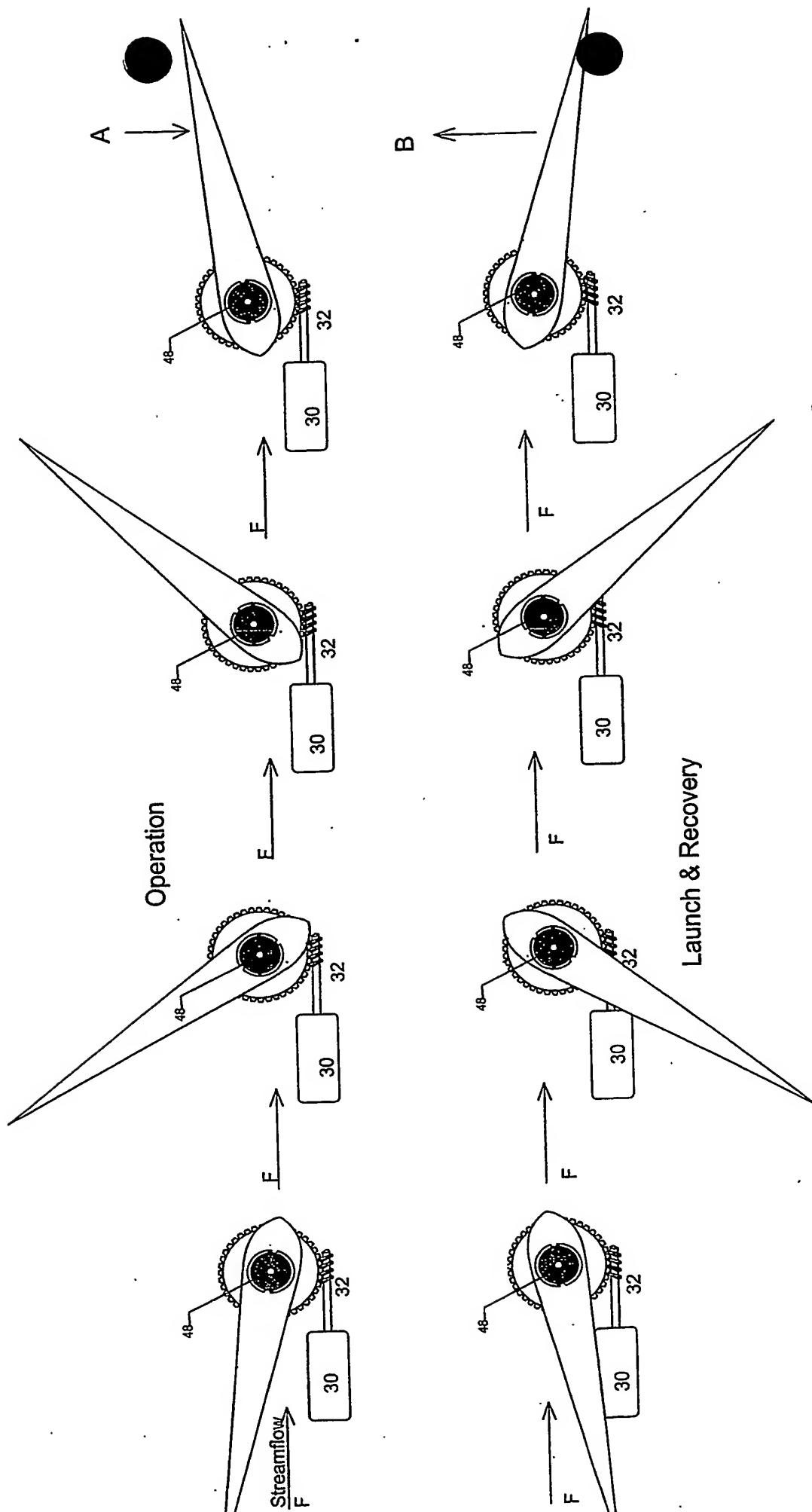
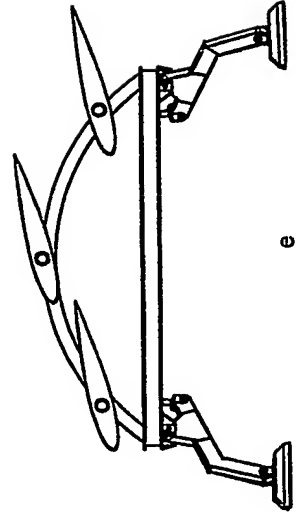
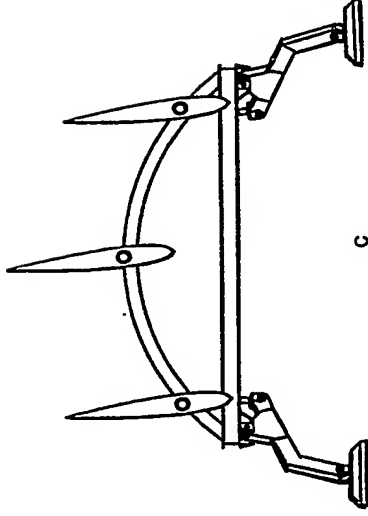
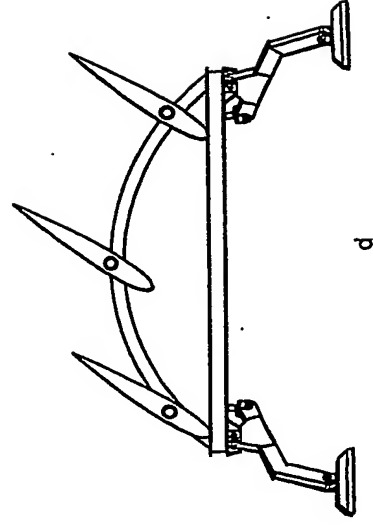
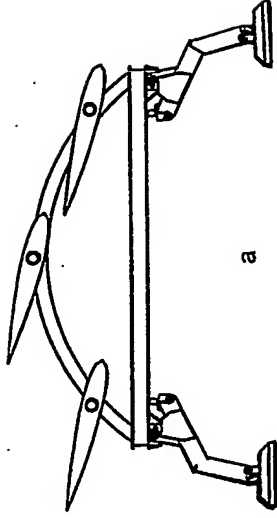


Figure 2

Previous flow direction



New flow direction

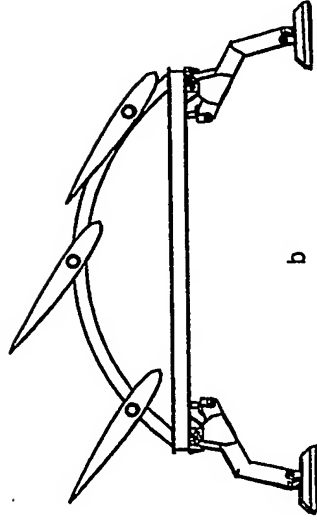


Figure 2a

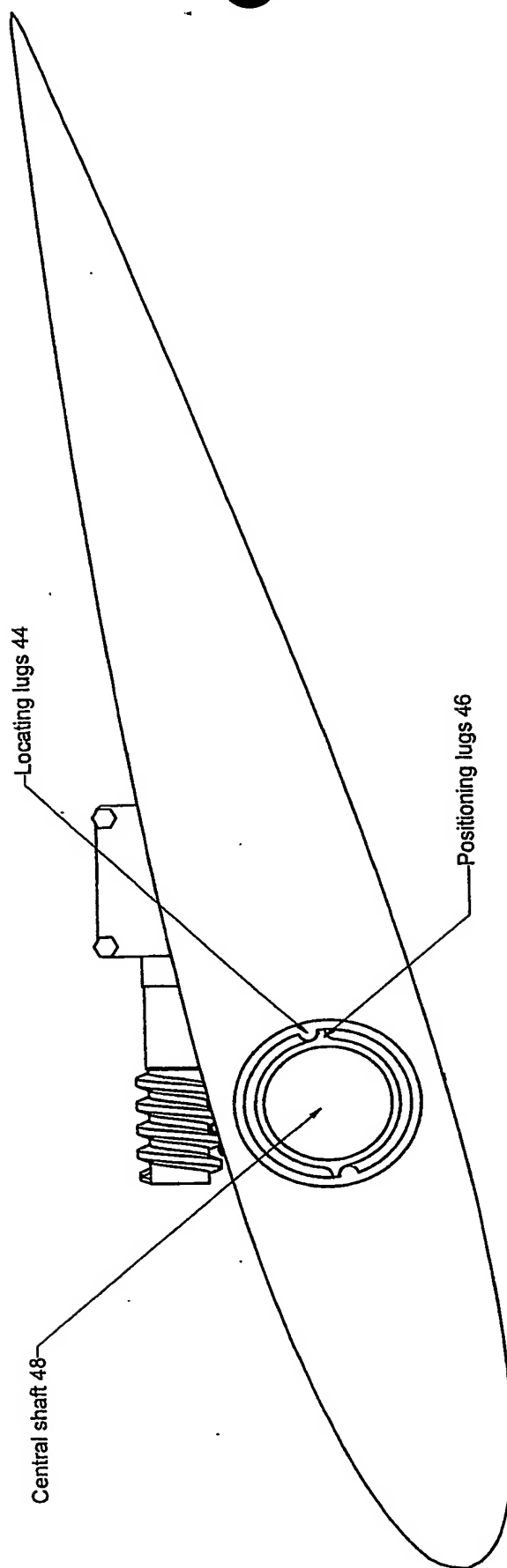
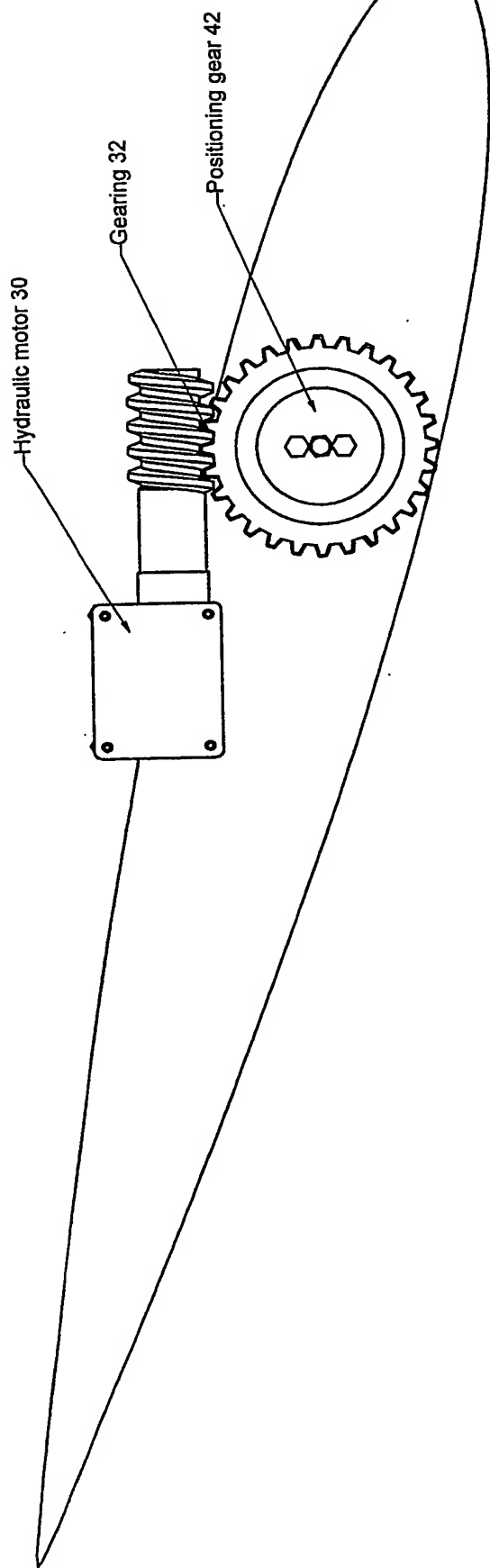


Figure 3

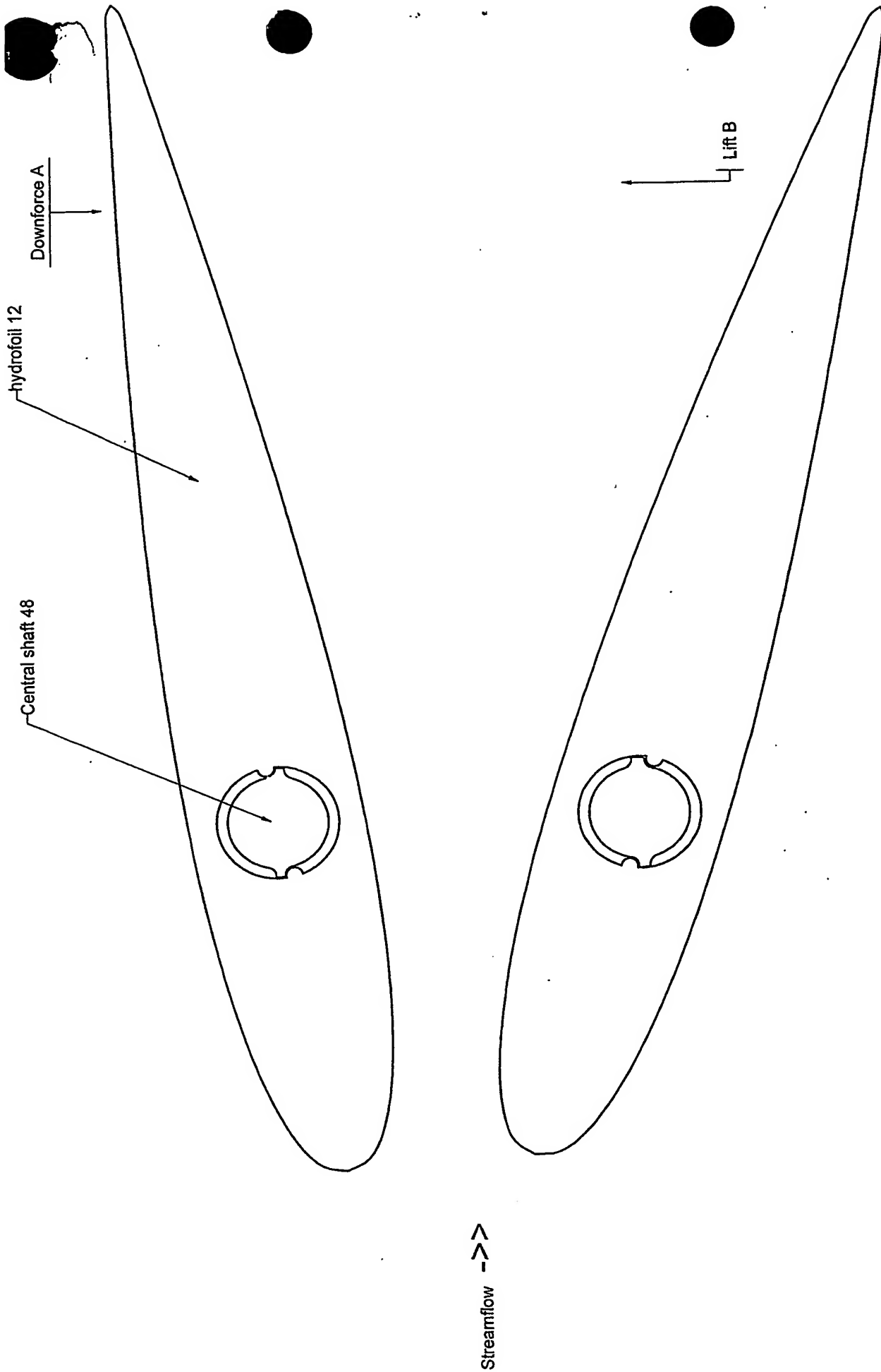
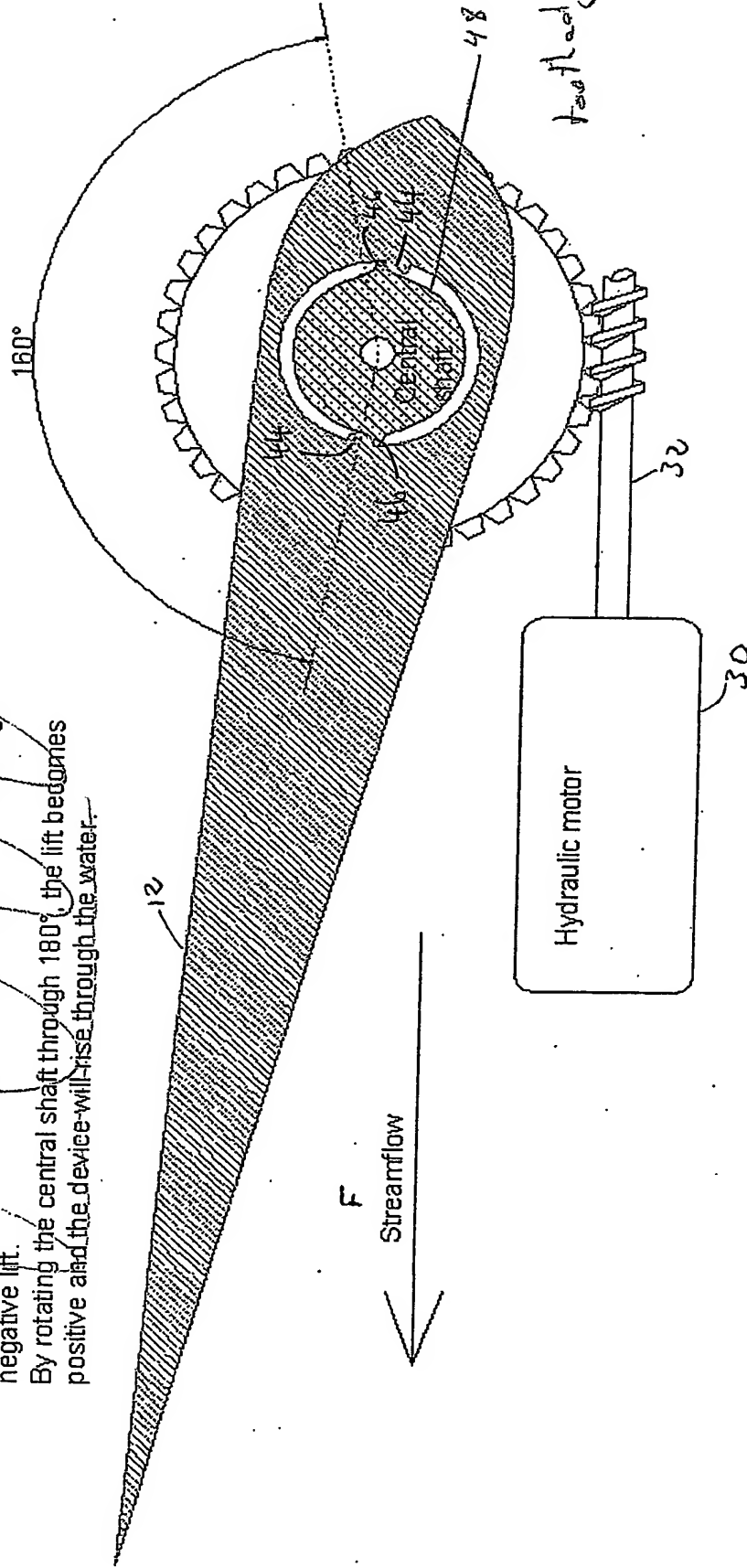


Figure 3a

Figure 3b

The foil is free to rotate about a central shaft, through an included angle of, say 180° which will maintain an angle of 10° to the horizontal. The 10° angle effectively becomes an angle of attack when the tidal stream reverses. Thus as the tidal stream reciprocates, the foil will maintain an angle of 10° , creating negative lift. By rotating the central shaft through 180° , the lift becomes positive and the device will rise through the water.



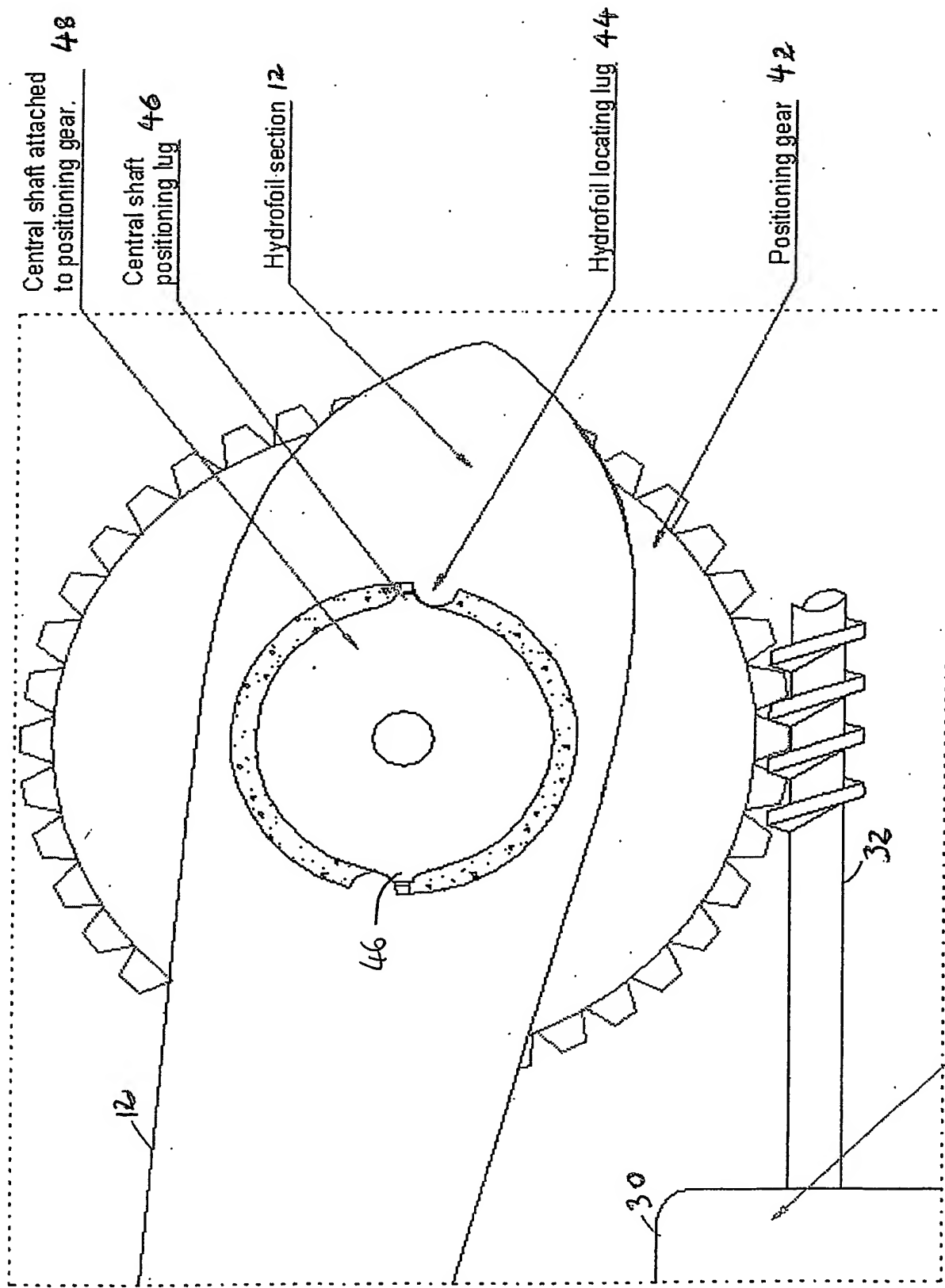


Figure 4